High filling factor vs. high channel count: which one wins in 3T breast imaging?

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Target Audience: Clinicians/scientists designing coils and/or interested in better breast imaging

Purpose: Higher signal to noise ratio (SNR) can translate in higher specificity of breast cancer detection. High temporal resolution dynamic contrast enhanced (DCE)-MRI imaging, enabling good kinetic data modeling, and high resolution diffusion weighted imaging, all afforded by higher image SNR, are generally accepted means to reduce the number of un-needed MRI triggered biopsies [1-2]. While increasing the channel count of an array is a straightforward solution for the image SNR problem, the choice of array geometry for this anatomy is difficult. Since breast sizes in the wide population vary between 125ml and 1900ml [3], an array that has the highest number of coils and the highest filling factor for each subject is usually not an option. While multiple cup size coils can be a choice in a research environment [4], such approach is not commercially viable, due to the high cost incurred to build these multiple options. Commercial breast coil design has to usually make the upfront choice between rigid setups, that use the maximum number of channels for all subjects (at the expense of small filling factors in certain subjects), to semi-rigid/movable coils that preserve good filling factors in all subjects, at the expense of using fewer coils in women with small breasts. We will analyze the trade-offs between the two choices in a 3T, flexible, 31 channel breast array, that has the capability of working efficiently in both scenarios.

Methods: A recently developed, 31 channel, flexible breast array is used in this work [5]. Nine spherical phantoms were first built to understand how the tuning and matching of each coil change as a function of breast size and composition. Three sets of 3 identical phantoms, of volumes 225, 525 and 1700ml, respectively were filled with water (+1.1g/L $CuSO_4$) and 0, 1.1 and 2.2g/l NaCl respectively. The sizes and salt concentrations of our phantoms are representative of sizes and breast compositions in a population of subjects. The tuning and matching of the coil elements were analyzed as a function of phantom. Following this set of experiments, which insured that the coil remains tuned and matched in any configuration, two scenarios, graphically depicted in Figure 1 were analyzed. In the first scenario, the performance of the coil in a torso phantom and the two medium size spheres, all filled with 1g/l $CuSO_4$ and 1.1g/l NaCl, with the coil tightly wrapped around the setup is evaluated (Fig 1 left). In the second setup, the coil is only very loosely wrapped around the spherical breast phantom, allowing most of the coils to pick up some signal from the breast spheres, at the expense of reducing the filling factor for each coil. SNR maps and g factor maps were obtained in both configurations using the methodology described in [4]. In vivo images were also obtained in both configurations, using a 3D spoiled GRE sequence (TE/TR=1.7/3.8ms). All experiments were performed on a GE MR750 3T system.

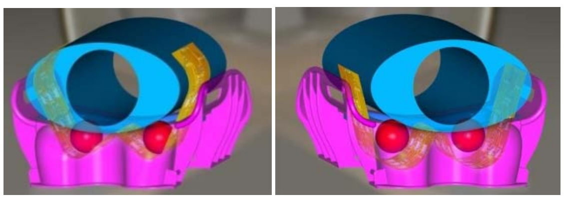

Figure 1: Illustration of "tight" (right) and "loose" (left) setups

Results: Table 1 presents the S11 for all five coils of the right center row of the array starting with the outermost (Ch1) and ending with the sternum coil (Ch5) as a function of "breast" size and loading. Note that relatively limited change in tuning/matching occurs for drastic changes in anatomy, confirming that good performance of the coil in the majority of population is expected.

Phantom	NaCl conc.	Ch1	Ch2	Ch3	Ch4	Ch5
Small	0	30.1	32.7	36.6	30.6	24.5
Small	1.1g/L	30.1	32.7	36.6	30.1	24.6
Small	2.2g/L	30.1	32.7	36.6	29.3	24.6
Medium	0	30.1	33.2	36.7	27.7	24.8
Medium	1.1g/L	30.2	33.3	36.6	27.4	24.6
Medium	2.2g/L	30.1	33.3	36.7	27.4	24.5
Large	0	32.2	34.7	38.4	24.9	25.7
Large	1.1g/L	32.1	33.4	37.3	24.5	25.1
Large	2.2g/L	32.1	32.5	36.3	24.8	24.6

Table 1: S11 [dB] for all right center coils of the array

Figure 3 displays g factor maps (acceleration factor $r=4$ in the R/L direction) and SNR maps for the 2 setups illustrated in Figure 1. While the SNR loss and dramatically higher g factor in the back of the subject for the loose configuration was expected and does not represent a problem, higher g factors and lower SNR are also noted in this configuration in the breast area. This trend is also confirmed in vivo, where 15-20% lower SNR is consistently noted in the breast area of the volunteer, scanned using the 3D SPGR sequence (Figure 4). This indicates that high filling factor is extremely important for obtaining the best quality breast images, and points to flexible breast arrays as one of the best choices in breast coil design.

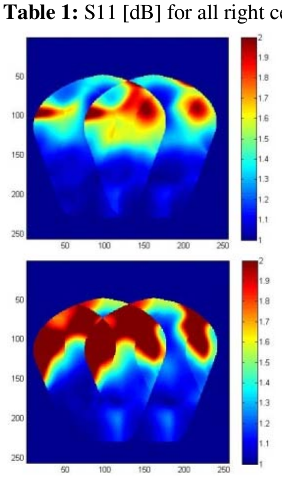

Figure 2: g-factors for tight (top) /loose(bottom) setup (r=4)

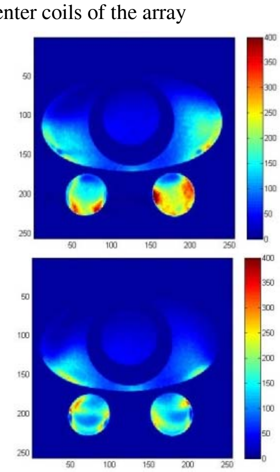

Figure 3: SNR maps for tight (top) and loose (bottom) setup

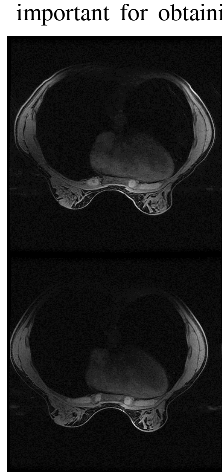

Figure 4: 3D SPGR images for tight (top) and loose (bottom) setups

Discussion and Conclusions: The tradeoffs between high filling factor and high number of coils in 3T breast imaging were considered. Results indicate that higher filling factor is preferable, leading to higher SNR and lower g factors than the case in which a larger number of coils are used, at the expense of lower filling factors. These results are also suggestive of the fact that, for the high channel count case, flexible breast arrays may perform better than arrays with movable parts, which may not be able to conform to the breast anatomy as well.

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References: [1] Thomassin-Naggara et al, Eur J Radiol, in press [2]Jansen et al, Phys Med Biol, 55:N473, 2010 [3] Deirdre et al, Int J Clothing Tech, 23:351 (2011) [4] Nnewihe et al, Magn Reson Med, 66:281 (2011) [5] Hancu et al, ISMRM 2013, submitted.